EFFECTIVENESS OF A PASSIVE FEEDLOT RUNOFF CONTROL SYSTEM USING A VEGETATIVE TREATMENT AREA FOR NITROGEN CONTROL

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ABSTRACT. *This study investigated the effectiveness of a solids basin and vegetative treatment area (VTA) for nutrient control as a low-cost alternative to runoff holding ponds for cattle feedlots. The discharge water and nutrients from the solids settling basin was effectively used for hay production. More total nitrogen was removed by the harvested hay than was applied in the runoff water. Electronic maps were produced to illustrate zones within the VTA where salt and nutrient accumulation occurred. Soil analyses in these zones indicated that surface soil nitrate levels closest to the discharge tubes had increased but it had not infiltrated into the soil. Periodic management of these zones may require removal using similar procedures to clean and reshape pen surfaces. Over-all the system demonstrate effective control of runoff water and nutrient utilization.*

Introduction

The Environmental Protection Agency issued a Final Rule on National Pollution Discharge Elimination System Permit Regulations, and Effluent Limitations Guidelines for Concentrated Animal Feeding Operations(CAFO) (40 CFR 122). The guidelines requires that CAFOs greater than 999 animal units contain runoff from a 25-year, 24-hour rainfall event (40 CFR section 412.26). Traditionally, earthen runoff retention ponds were used to meet these requirements; however, construction costs, equipment, and labor posed monetary hardships, particularly on smaller operations. Provisions in the CAFO rule allow for alternative systems provided they meet all requirements.

The overall objective of this study was to evaluate the vegetative treatment area and provide information for design modifications to improve effectiveness. Specific objectives were to: 1) determine mass balance of total nitrogen (TN) entering and exiting the VTA, 2) map solids basin discharge water distribution in the VTA using electromagnetic induction and map interpretation methods, and 3) analyze soils at various points in the solids basin and VTA for nitrogen loading and infiltration.

Material and Methods

Eight pens (30 m X 90 m each) with an average 6% northward slope were stocked with 70-80 head/pen of finishing beef cattle (550 kg) for approximately 180-day cycles (Woodbury et al, 2002 and 2003). A 300 m long solids basin and terrace was constructed to separate solids and uniformly discharge runoff for nutrient and water utilization (fig. 1). Discharge pipes were installed through the terrace at the same elevation to provide uniform distribution (fig. 1). The ratio of VTA to pen surface was approximately 2:1. The runoff control system was instrumented to measure runoff coming off the pens and discharge coming out of the basin. Berms were constructed at the down-gradient end and sides of the VTA to isolate it from the surrounding environment (fig. 1). Sampling equipment was installed to sample soil water at a depth of 1.8 m with in the VTA (fig.1).

Hay was harvested using conventional equipment. Multiple samples were collected just prior to baling to determine dry matter mass and TN (Table 1). All precipitation events greater than 20 mm were used to estimate runoff. Mass of TN entering the VTA was adjusted for the mass of TN leaving the basin in the harvested hay (Table 1).

Soil samples were collected in the VTA to a depth of 3 m in increments of 0.3 m. Locations of the sampling sites were based on apparent electrical conductivity (EC_a) maps that were differenced to illustrate zones of nutrient accumulation (fig. 2) (Eigenberg and Nienaber, 2003). A ridge formed from a removed fence line served as a control site because it did not receive any runoff. Three transects radiating from the terrace were selected. Two transects (WD and ED) were selected near two separate discharge tubes, and one transect (RDG) was selected on a ridge that received no discharge, a condition that existed prior to construction of the VTA. Five soil cores were taken along each transect (fig. 3).

Results and Discussion

Four years of hay crop were removed from the VTA (Table 1). Three of those four years, more nitrogen was removed by the hay crop than was deposited by the runoff discharge (Table 1). This net removal of TN indicates the VTA was effectively utilizing the nitrogen discharge by the basin. Also, attempts were made to extract soil water from the VTA at the 1.8 m depth. No water was ever extracted. Therefore, the runoff system appears to be sufficiently sized to retain and utilize water and TN discharge from the solids basin.

A pattern of increased EC_a near the basin discharge tubes is illustrated by fig. 2. Analyses indicated nitrate-nitrogen (NO_3-N) concentrations were higher in the upper 0-0.15 m horizon for all sampling sites of west drainage transect (fig. 3). Elevated NO_3-N concentrations have been localized near the soil surface. This is illustrated by the sharp drop in concentration to levels comparable with the ridge transect below the depth of approximately 0.5 m (fig. 3). No elevated NO_3-N concentration was measured for any sampling sites (RDG 1 - RDG5) along the ridge transect (fig. 3).

Relative elevations were taken at the bottom of the inlet end of each discharge tube. These relative elevations were normalized to the elevation of discharge tube 2 (fig. 4). Coordinates of the discharge tubes were located on the maps to evaluate discharge distribution performance. Tubes with the lowest elevations corresponded with VTA area that had increases in EC_a values (fig. 4). Elevation had a dramatic impact on distribution, even though the elevation difference from highest to lowest discharge tube inlet was less than 30 mm. The discharge tube with the lowest elevation could be discharging up to 4 m^3 hr^{-1} before the highest elevation tube began discharging. This unequal discharge was exacerbated by low-intensity and short-duration storm events. Remedies for maintaining constant relative elevations among the tubes could include an adjustable inlet weir plate on each tube. This would allow for periodic adjustment to maintain uniform discharge from each tube, thereby improving distribution.

Conclusions

The alternative runoff control and treatment system demonstrated very good nitrogen control. Distribution of solids basin discharge water and nitrogen across the VTA were not as uniform as planned resulting in accumulation zones near the basin discharge tubes. This accumulation remained near the surface and techniques similar to clean and re-shaping pen surfaces should improve long-term nutrient control effectiveness. Discharge tubes inlets were initially set at the same elevation but changed slightly over years. This change has concentrated basin drainage in isolated portions of the VTA. Periodically adjustment of the inlets would improve distribution. No water was measured exiting the VTA indicating the runoff was effectively used by the hay crop for production.

References

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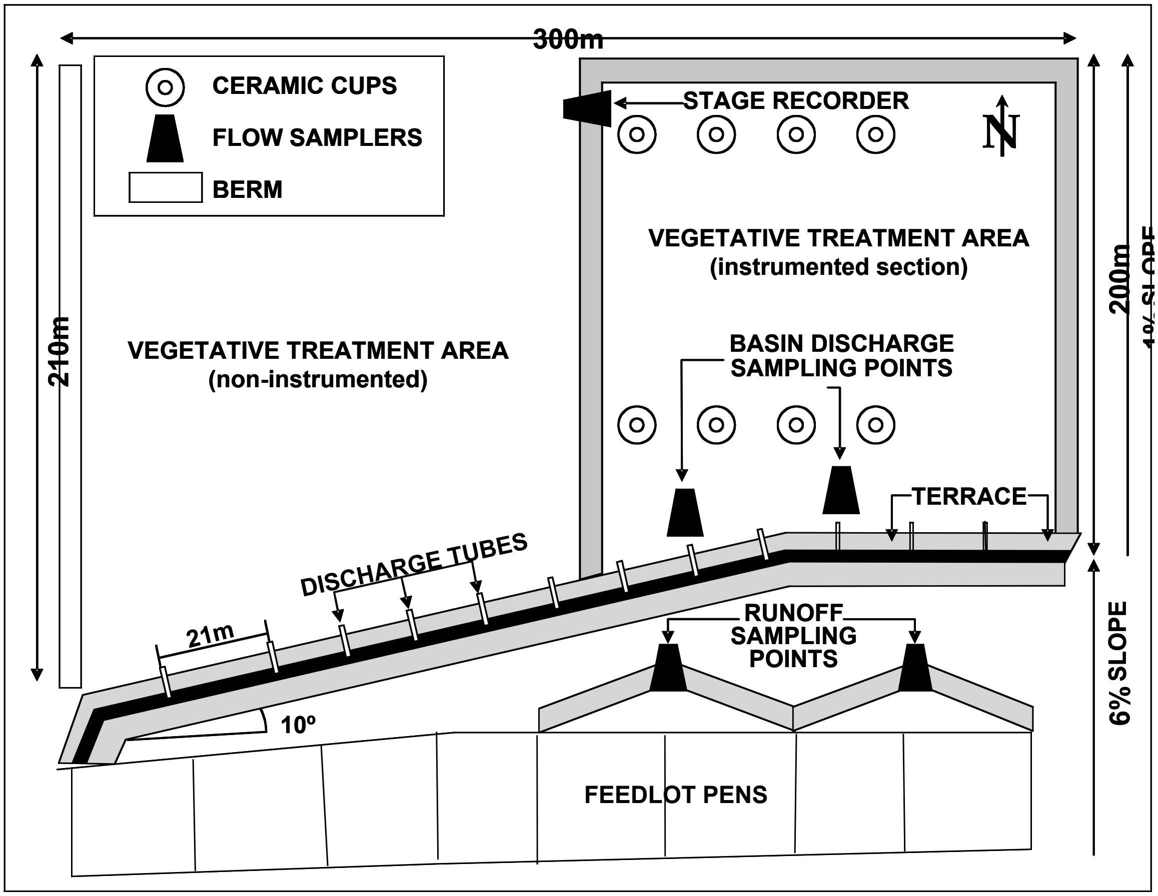

Figure 1. Plan view showing the relationship of the feedlot pens, solids basin with terrace, discharge tubes, and the vegetative treatment areas. Note the addition of the flow samplers, ceramic cups, and berms for isolation of instrumented section of the vegetative treatment area.

Table 1. Precipitation, estimated runoff, and mass balance of total nitrogen entering and exiting the vegetative treatment area during the study period.

Year	Precipitation	Estimated Runoff	Hay Crop Total Mass	Total Nitrogen Entering	Hay Crop Total Nitrogen	VTA Net Total Nitrogen
	mm	m-3	kg	kg	kg	kg
2000	487	3940	34,100	360	580	-220
2001	602	3550	25,100	432	420	+12
2002	393	1800	19,360	0	435	-435
2003	450	1950	23,050	0	320	-320

The basin area was approximately 900 m^2.
Mean historical precipitation near the study site during the study period 4/1 through 10/31 is 606 mm.
[1]Evaporation and basin seepage between rain events eliminated basin discharge.
[2]A leaking drain tube seal minimized basin discharge during 2003.
[3]Value assumes no basin discharge.

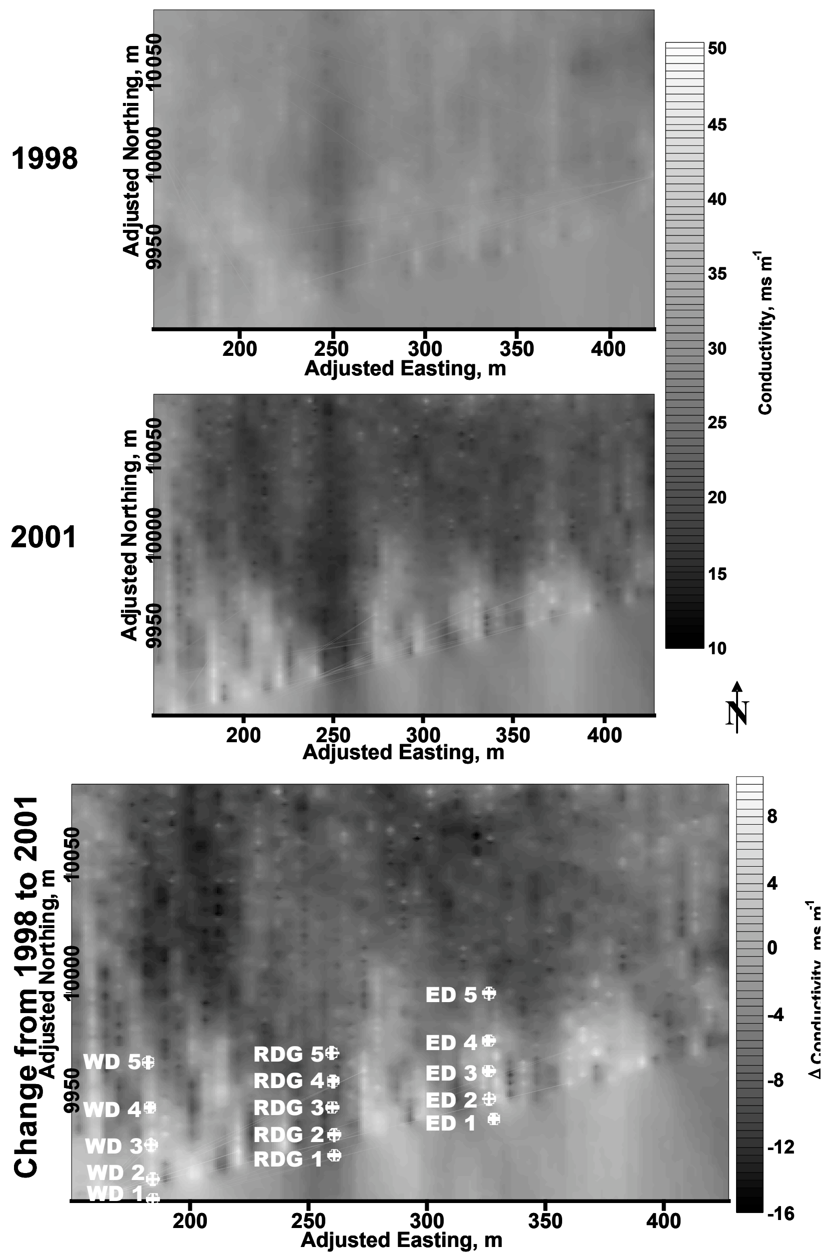

Figure 2. Electromagnetic induction maps of the vegetative treatment area. Top map was generated on May 13, 1998; middle map was generated on May 14, 2001; bottom map is a grid-differenced image illustrating changes in apparent electrical conductivity from 1998 - 2001. Note: WD 1-5, RDG 1-5, and ED 1-5 designate sampling points along west and east drain, and ridge, respectively. (Adjusted Northing = Northing - 4487000; Adjusted Easting = Easting - 570000).

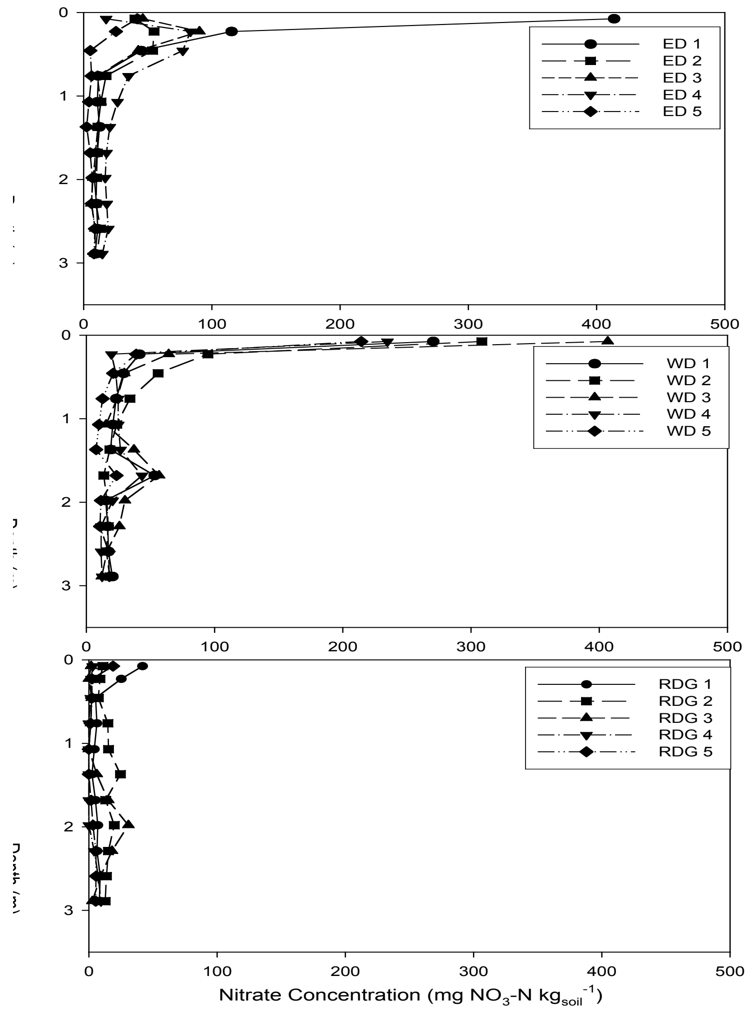

Figure 3. Nitrate-nitrogen concentrations for the east drain (ED) and west drain (WD) paths, and ridge (RDG). Note sample locations 1-5 correspond with those identified in figure 3.

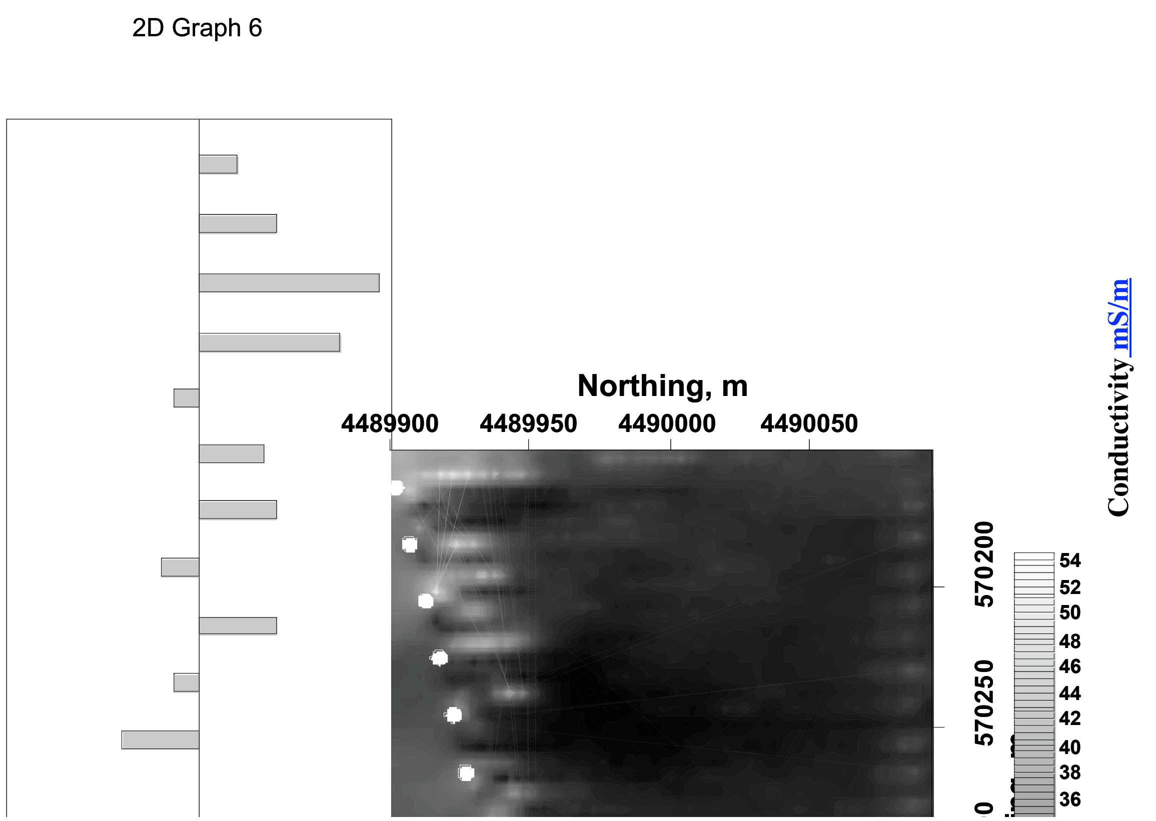

Figure 4. Electromagnetic induction map with the relative elevation of each basin discharge tube.